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AUTHOR Thurman, Richard L.; And Others
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ABSTRACT

Described are the rationale, development and utility with mentally retarded children of the Peabody Mathematics Readiness Test (PMRT), an instrument designed to assess mathematical readiness of normal first graders and identify children who would experience difficulty with first grade mathematics. It is explained that the PMRT was intended to pinpoint areas of deficiency and help devise appropriate remediation activities. The PMRT is said to be composed of two parts: discrimination items and line drawings to be copied. Further, it is noted that the test can be group administered, has a theoretical rationale, and has been empirically validated. Discussion of the PMRT's historical development covers such aspects as establishment of scoring schemes and weighting systems, as well as research on the effectiveness of remedial materials developed for normal first grade students. Reviewed is an experiment in which 737 normal first grade students and 175 educable mentally retarded students matched for MA were administered the PMRT. Cited among findings is the basically equal performance between normal first grade and mentally retarded Ss on the discrimination tasks of the PMRT. (CL)

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The Peabody Mathematics Readiness Test:

Rational and philosophy, historical development
and utility with mentally retarded children.

Richard L. Thurman - Lloyd I. Richardson

University of Missouri - St. Louis

Otto C. Bassler

George Peabody College for Teachers

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Peabody Mathematics Readiness Test

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Abstract

The Peabody Mathematics Readiness Test (PMRT) has been developed to assess mathematics readiness of normal first graders and identify children who would encounter difficulty in first grade mathematics. The experimental edition of the PMRT was developed in 1970. Since that time, research for normative purposes has been a continuous endeavor in various areas of the United States. For the last two years, research has been conducted on the potential usefulness of the PMRT with mentally retarded children. This manuscript has attempted to synopsise the entire developmental process of the PMRT.

Rationale and Philosophy:

The concept of readiness has been important in reading for a long time but there has been less work in mathematics readiness. To be sure there are tests which purport to measure readiness in mathematics but most of these in reality are achievement tests. Items such as, "Mark the box that has 12 dots in it" or "Put a mark on the numeral 56" measure to some extent the mastery that students have of first grade objectives. Our search of the existing tests indicated a need for a mathematics readiness test that is designed to determine the extent to which students are ready to begin a study of first grade mathematics, not the extent to which they know first grade mathematics.

There are two views that have emerged from the extensive work that has been done in the area of reading readiness. One of these views is that tests should be administered to determine when a student is ready to read. If the test results indicate lack of readiness, instruction should be delayed until readiness is achieved. The other view is that readiness tests do not tell when to begin teaching reading but rather the results of these tests tell what the student must do in order to be ready to learn to read. This latter view is the one taken as the Peabody Mathematics readiness Test (PMRT) was being developed. Our concern was actually twofold: first we wished to identify beginning first grade students who were likely to experience difficulty in first grade mathematics; and second, we wished to identify those areas in which students were deficient. If this second purpose could be accomplished, it would then be possible to design remediation activities to ready students for learning first grade mathematics.

Much of the current emphasis in mathematical readiness skills has evolved from the work Piaget (1952). Among the concepts which he felt to be important in the development and understanding of number are seriation, classification, ordina-

tion, cardination, and conservation. To attain success in first grade mathematics, students must either have these capabilities upon entering or there must be a program of experiences which enable them to attain them. This is so because of the emphasis that is placed upon the acquisition of number concepts in the first grade mathematics curriculum.

One problem with the assessment of readiness using Piagetian tasks is that most of them require individual administration. Although this is enlightening for the teacher, it is also a time consuming task and not feasible for busy elementary school teachers. It appeared to us that much of the same results might be obtained if youngsters could be forced to make discriminations between concepts that were pictured. This would have the advantage of a group administered test with directions simple enough for young children to carry out.

Further, instead of having one object different, there may be more than one dimension along which objects may be separated into groups. Suppose for example that a decision is to be made either on the basis of the configuration of a line drawing or the number of sticks that were needed to construct the drawing. The question is "which object is most different" or "which object is not like the others?" The decision that a student makes to answer this type of discrimination

Insert Figure 1 about here

task (see figure 1) may be indicative of his ability to cope with learning about numbers. If the youngster selects the first line drawing as most different, he is responding on the basis of configuration. If he selects the second drawing, he may be responding on the basis of length, and if he selects the third drawing as most different, he is responding on the basis of number. We hypothesized that for items of this kind a student that responds on the basis of number would achieve better



Figure 1. Example discrimination task

in the first grade than a student who responded on the basis of configuration. Parenthetically, those of you familiar with Piagetian tasks may recognize this as a picture of one of his tasks used to test if youngsters can conserve length.

In the initial stages of test construction, a wide variety of these choice situations were developed. The various choice dimensions that were used were taken from the professional literature. There is a heavy reliance on the work of Piaget, (1952); however, the research of others such as Suchman and Trabasso (1966) and Kagan and Lemkin (1961) was also influential in our decisions. These researchers investigated young children's choice for color, form, or size as dimensions for grouping. After constructing a variety of items and after initial pilot work with students, it was decided to limit the number of dimensions on the test to five which were labeled configuration, containment, number, shape and size. Each item was constructed using three line drawings, each of which were different from the other two on some dimension. It was felt that these were important for success in first grade mathematics and provided an adequate base for discrimination.

The configuration dimension consisted of line drawings that were characterized by several conditions. They were: 1) the same line drawings were used but there was some reorientation; or 2) the same figure was drawn but some distortion, i.e. some lines were straight while others were curved, lines were omitted or extended. Containment is an inside-outside dimension. If a student responds to containment, he would be making a decision on the basis of whether some of the line drawings are in the interior of another line drawing or not. The number dimension required students to make a decision based upon the number of objects (dots or shapes) in a line drawing. If youngsters responded to the shape dimension, they were making a choice based upon the way the dots were arranged in a picture or upon different geometric sets of points such as triangles, circles, etc. Size was a large-small

dimension; that is, a student would make a choice based upon whether it was larger than or smaller than the other line drawings.

An example of an item might help to illustrate the manner in which these dimensions were used. To test whether a student would select the number dimension or the containment dimension, the following item was developed.

Insert Figure 2 about here

If the youngster chose the first drawing we assumed that he was responding on the basis of number since there are 4 circles in this drawing as compared with 5 in the other two. Selection of the third drawing would indicate a choice based upon containment since 4 circles in this drawing are outside the pentagon while all circles are inside the pentagon in the other two drawings. Our analysis indicated no reason for selection of the second drawing.

Students were directed to make an X on the line drawing that appeared most different to them and in this way indicate to us the dimension upon which they were making their choice. Items were scored based upon apriori considerations about dimension. These were based upon a hierarchy that was developed through initial work with some of the test items and which also had a theoretical basis (Wohlwill, 1968; Brashear, 1970). The final hierarchy used in order of decreasing importance is: 1) Number, 2) Containment, 3) Size, 4) Shape, 5) Configuration. Thus if an item required a student to make a choice between number and containment as in the last illustration, we assumed that he was operating at a higher level if he chose the number dimension rather than if he made the containment choice. Scores were assigned accordingly. The scoring for each item was determined in this way- each choice which indicated the higher ranking dimension was given 3 points; a choice which indicated the other dimension was given 2 points; and the last choice for

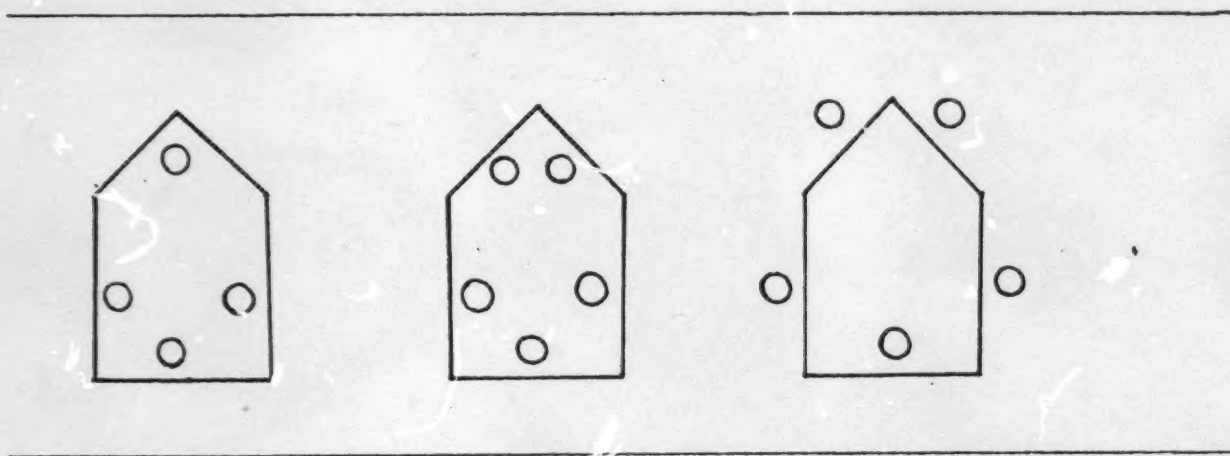


Figure 2. A PMRT discrimination item

which there did not appear to be any logical reason was given 1 point. The scoring and construction of items was where we were most influenced by the work of previous researchers and theory builders.

A second part of the Peabody Mathematics Readiness Test included 5 line drawings for the students to copy. This type item was borrowed from reading readi-

Insert Figure 3 about here

ness tests. Kephart (1970) described in detail the developmental stages which he feels are necessary to copy figures. Most of these are also prerequisites for completing first grade mathematics successfully. For example, when drawing a square the child would have to decide where to start. This point would become his reference point. Now he must be able to move from the reference point in the required direction and determine the stopping point for this line. This process must be continued until he completes the figure and reaches the final stopping point. In order to copy the figure correctly, the student must have developed eye-hand coordination, that is the child must be able to move his eye along the stimulus and then translate the image into body movements. A second skill that is necessary for successful completion of the copying task is dexterity of movement, that is the ability to hold the pencil with ease and to guide it in the direction intended.

Both of these skills are important in first grade mathematics where part of the program deals with geometry and measure. To successfully complete this, students must be able to accurately perceive the physical world. Eye-hand coordination is essential to counting objects for the student must point to each object as it is counted. Finally in order to write numerals, as well as words, the

Directions: In each box there is a drawing. In the same box and underneath the picture, draw a picture which looks like the drawing. Do this for each picture on the page.

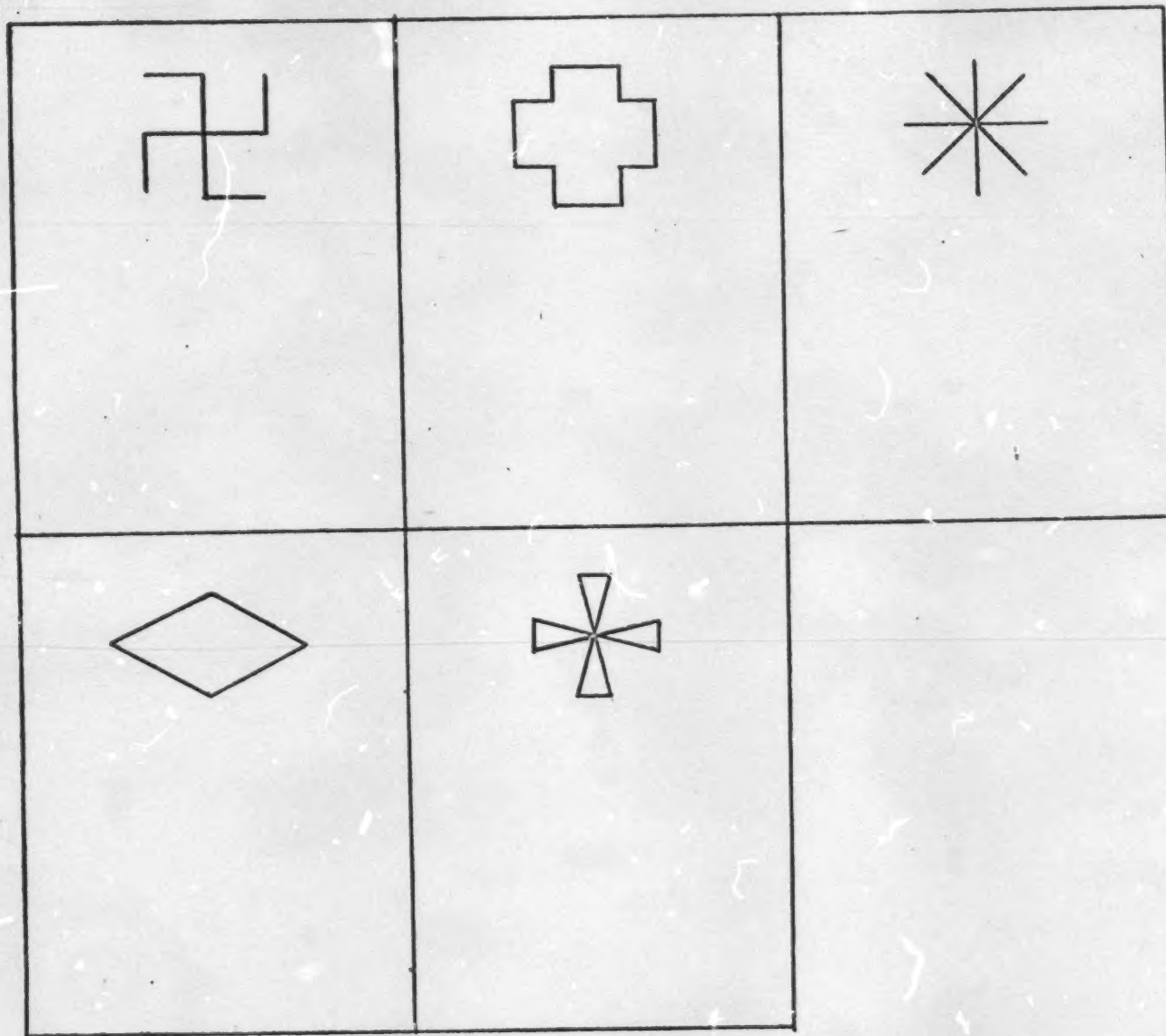


Figure 3. PMRT Drawing Test Items

the student must have attained copying skills similar to these.

Scoring of the drawings was made on the basis of 0, 1, or 2 points. If the drawing was technically correct and of approximately the same size as that shown to the student, 2 points were awarded; if the students indicated that he possessed eye-hand coordination but did not have the fine muscle control necessary to complete the drawing correctly, 1 point was awarded; if the student could not complete the drawing correctly, 0 points were awarded.

The entire test was designed to be administered late in the Kindergarten year or at the beginning of first grade. Pilot work with the instrument indicates that it is successful in identification of students who would experience difficulty in first grade mathematics. When these students are identified, it is possible to plan and implement a specific remedial program which would serve to eliminate these deficiencies and to provide the student with a better first grade mathematics program. Some success has been achieved in planning remediation activities for students who have scored low on this test. To date, the specific scales have not been analyzed to try to determine the specific areas of weakness that are indicated by low scores on one scale. Summarizing, we feel that we have developed a mathematics readiness test that can be group administered, has a theoretical rationale and which has been empirically validated.

Historical Development:

As described in the prior section, the PMRT was designed in an effort to identify those students who would experience difficulty with first grade mathematics. Our eventual goal was to develop remedial materials, related to the test, to increase pupils' first grade mathematics performance.

The PMRT consists of two parts: a discrimination test and a drawing test. The discrimination test requires the student to decide which of three line drawings

is most different from the other two. The drawing test requires the student to copy a line drawing to the best of the student's ability.

In developing the test, items that involved multiple discriminations were developed. From the pool of initial items, a total of about 50 items were selected as meeting at least face validity. A number of items were discarded at this point because there existed no plausible explanation of what they measured.

In the first phase of development, students in grades K, 1, and 2 were individually administered the tests. The subjects were interviewed by one experimenter while one observer took notes on the testing situation. Initial testing sessions were also tape recorded and students were asked why they answered in a certain way. The tapes and observation notes proved very valuable in determining a scoring scheme.

It was decided that if an item did not evoke different responses between grades K and 2, then serious consideration would be given to withdrawing the item from further use. Items such as these were not considered as a good discriminators of success in first grade mathematics.

Analysis of the tapes and individual testing resulted in a reduction in the item pool to 41 discrimination items. Once the data was collected, all teachers (of the students) were asked to rate their students on a seven-point scale. A rating of one reflected low mathematics ability, a seven rating reflected high mathematics ability. The data collected from students, along with prior theory were used to develop a scoring system.

Using each test item as a predictor and the teacher rating as the criterion, multiple linear regression was used to develop another weighting system. All possible combinations of weights, for each item, were tried until the best possible prediction of the teacher rating was obtained. The weighting system produced by the multiple regression technique was then compared to the weighting produced

from the theoretical basis. Surprisingly most weightings agreed; but when they did not agree, the empirically generated weighting was adopted. Items which had no strong theoretical basis for weighting were left as they appeared in the final weighting system generated by the regression procedure. The resulting weighting system has been used for all subsequent work with the test.

Using the final weighting system the 80 tests were scored. The interaction of grade level with both the discrimination test and the drawing test was investigated and found to be non-significant. Both the discrimination test and drawing test were, however, found to be significant predictors of student success when grade level was co-varied out using multiple linear regression techniques. This analysis also indicated that sex of subject did not significantly increase prediction of success in mathematics.

Students receiving 1, 2, or 3 on the teacher rating were considered to need remediation while those receiving a 4 or higher were not. Using the scoring scheme and predicting the dichotomy of "needing" or "not needing" remediation, it was found that the test predicted accurately 88 percent of the time. In predicting the "need remediation" group, the test only proved effective in identifying 46 percent. The equation used in these predictions contained only the total discrimination test score and drawing test score. The investigators felt that better prediction could be obtained by using subscales on the discrimination test.

The second phase of development was to administer the test to a sample of 800 students from public schools in Connecticut and Louisiana. The tests were administered to first grade classes as a group, by the teacher during the first week of school. At the end of the school year, May, each teacher rated their students on a seven-point scale. The tests were scored according to the previously determined system, and the sum of weighted scores was used to predict the teacher rating. The drawing test scores were not entered into the analysis at this point.

because it was felt that no improvement could be made in the scoring or use of the drawing part for predictive purposes. Using the discrimination test total score, it was possible to obtain only 40 percent accuracy on those students needing remediation.

The data was then subjected to a factor analysis. The data was randomly divided into two subsamples, sample A and sample B. The prior data from the phase I sample had been factor analyzed and 4 weak factors emerged. These factors did not replicate in sample A. Thus, in phase II, sample A was used to produce a new set of factors that were then replicated in sample B. Two of the factors from sample A seemed to replicate in B, the factors represented number and shape. Although the analysis was somewhat inconclusive regarding the other factors, it did indicate general factors related to the theoretical dimension.

To increase the percentage of students correctly identified as needing remediation, the test items were separated into five subscales, based on the underlying dimensions (number, containment, size, shape, configuration). Using the previously developed scoring scheme, each item was analyzed to determine which dimensions were involved. The dimension that received the highest weight was the subscale in which the item was placed. Using the subscales increased prediction.

Each subscale was summed separately, producing five subscale totals instead of one total score. Using multiple linear regression analysis, 70 percent accuracy was obtained in predicting the actual teacher rating using the five subscales. Prediction of those pupils needing remediation was about 65 percent. Of the 35 percent who needed remediation but were predicted as not needing it, over one-half received a teacher rating of 3 indicating they were borderline cases.

The following year Beers (1973) attempted to assess the effectiveness of specially designed remedial materials developed for normal first grade students predicted as not ready to begin first grade mathematics. Subjects consisted of

72 pupils (42b, 25g) from 4 kindergartens in Nashville, Tennessee. Subjects scoring in the lower half of each class on the PMRT were then randomly assigned to experimental and control groups. Each group contained four subjects.

The experimental group from each school received eight one-half hour training sessions using specifically developed remedial materials. Remedial materials utilized basic Piagetian concepts such as seriation, cardination, ordination, 1 to 1 correspondence, classification, reversibility, and conservation. Training was held twice per week. Concepts were presented as tasks or problems in game format to the small group in order to stimulate interactions. After training, post-tests were given.

- (1) significant treatment effect ($\alpha = 0.05$) level in favor of the experimental group, on the Metropolitan Readiness Test. Experimental groups had a mean decreased from 12.13 to 11.19.
- (2) There was a significant treatment by school interaction. Looking first at each school and secondly at each treatment group, no significant increase in mean scores were identified for any school. There was, however, a significant difference between the school means for the experimental group, but not for the control group. Thus it seems that the treatment has different effects in different schools.

Basically, students predicted as needing remediation, who are in fact remediated show significant increase in scores on the mathematics section of commercial readiness tests like the Metropolitan Readiness Test.

Utility with Mentally Retarded Children:

Such authors as Hutt and Gibby (1965), Kirk (1964) and Smith (1967) have expressed the need for more and better research in the area of mathematics for the mentally retarded. There is a surprising lack of research in that area, and especially research involved with the concept of readiness. Readiness, especially in

reading, has proven to be of vital success for instructional purposes. It would seem that the area of mathematics should be of equal importance, especially in terms of instructional needs for success in mathematical functioning. It also appears as though any and all possible prerequisite readiness skills would be applicable to mentally retarded children in view of their unique educational concerns and needs.

The PMRT, through previous research (Beers, 1973), has been shown to be a useful diagnostic tool with normal children. With this information base, it was decided to extend this research and assess the utility of the PMRT with mentally retarded children (Richardson, Thurman, and Bassler, 1975).

Methodology

Subjects:

The subjects were 175 mentally retarded students and 737 normal first-grade students. The mentally retarded children were attending special educational classes within a large, midwestern urban area. The first-graders were attending various classes taken from a four-state (one midwestern, one eastern and two southern) sampling.

The sample of mentally retarded subjects had met the investigation criteria of an IQ range from 50 to 75 ($\bar{X}=60.28$) and mental age (MA) range of 6-0 to 6-11 years old ($\bar{X}=6-6$ years). The tests used to determine the IQ's were the Stanford-Binet and/or WISC. It was hypothesized that the mental age requirements for the mentally retarded would be comparable to the ability level of normal children entering first grade.

Procedure:

All the special educational facilities within the midwestern metropolitan area had been invited to participate in the study. With only one exception, all the special facilities agreed to participate. First, the students records were

searched to find the mentally retarded subjects who met the specified criteria to be included in the study. A total of 193 mentally retarded students were found who met the specific criteria.

Next, undergraduate special education students from a large, midwestern university were trained on the procedures of how to administer the PMRT. The PMRT, as described earlier, has very simple administration directions. Basically, the administration task was involved with giving the direction ("mark which one is most different from the other two") and observe to see if the required task was completed. Although the PMRT was designed to be group administered, it was decided by the investigators to limit the mentally retarded group size. The final opinion was that the preferable test grouping for mentally retarded students was two (2) and certainly no more than three (3) students. This decision was made to facilitate the test administrator so that he would arrange himself to give the best verbal directions and to observe each student as they completed the required tasks for the test. Thus, the test administrator could be sure that the students were completing the designated items at the proper time. Each test administration group took approximately fifteen (15) minutes. All the subjects were tested in a two-day period, early within the fall semester of the school year.

The following spring semester (in May), the subjects classroom teachers were asked to rate each of the subjects mathematical abilities relative to the other children within their class. These ratings were presumed to be indicative of each subjects mathematical performance for that school year. Two teachers failed to return this information which accounted for the attrition rate of eighteen (18) subjects.

Results:

The results of the study found basically equal performance between normal first-

grade and mentally retarded subjects on the PMRT. The five discrimination subscales of the PMRT (number, containment, size, shape and configuration) all had insignificant statistical differences. However, significant differences were found in the drawing test subscale and teacher ratings. The results of this analysis can be seen on Table 1.

Insert Table 1 about here

Conclusions:

The study has the following limitations:

- 1) The sample of mentally retarded subjects were restricted to only one geographic region.
- 2) More pre-test trials are needed to prepare and acquaint the subjects with the task. The experimental edition of the PMRT presently has only one (1) pre-test trial which appeared adequate for normal first graders, but was totally insufficient for test preparation purposes with mentally retarded subjects.
- 3) Group size is important for administration purposes. For normal first grade children the entire class could be administered the test. Our experiences found that best results were obtained with groups of three (3) or less mentally retarded children.
- 4) Teachers ratings for mentally retarded subjects tended to be more restrictive than teachers ratings for normal first-graders. Rating criteria should be established as guidelines for teachers,
- 5) More research should be conducted with the PMRT with mentally retarded children for normative purposes.

Although the present study has a limited scope, in view of the results it can be concluded that the actual performance of normal and mentally retarded subjects on discrimination tasks were basically equal. As can be viewed on Table 1, the

Table 1
PMRT Results for Normal
and Mentally Retarded Subjects

	N	Range Low High	$\bar{X}$	Sd
<u>Number Subscale</u>				
M.R.	175	7----24	17.74	2.35
Normal	737	7----24	18.08	2.03
<u>Containment Subscale</u>				
M.R.	175	9----18	14.16	2.12
Normal	737	6----18	14.26	2.08
<u>Size Subscale</u>				
M.R.	175	5----12	8.90	1.25
Normal	737	2----12	8.73	1.40
<u>Shape Subscale</u>				
M.R.	175	5----12	9.16	1.63
Normal	737	2----12	9.34	1.48
<u>Configuration Subscale</u>				
M.R.	175	11----24	17.56	2.22
Normal	737	4----22	17.64	2.41
<u>Drawing Test</u>				
M.R.	175	0----10	4.51*	3.06
Normal	737	0----10	6.41*	2.56
<u>Teachers Rating</u>				
M.R.	175	1----7	3.58	1.74
Normal	737	1----7	4.44	1.83

*p < .01

differences in group performances on the five discrimination subscales of the PMRT was insignificant.

There was, however, significant differences on the drawing test section of the PMRT. These results are presently under investigation to determine the exact nature of these differences. The major concern about the results of the present study is whether these differences will have implications toward the development of remediation procedures.

A second difference was found in the teachers ratings. The results suggest that special education teachers generally tended to use a more restrictive rating scale (1-5) as opposed to regular elementary teachers who used the entire scale (1-7) when rating their students. In view of the research involved with teacher expectations and its implication on student achievement, these results are also presently being investigated.

In summary, previous research (Beers, 1973) has proven the utility of the PMRT as a diagnostic instrument with normal children. The present study, although there is a need for further research and follow-up to be conducted, has found the PMRT to be a potentially useful as a diagnostic tool for the mentally retarded.

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AUTHORS

Richard L. Thurman, Ph.D. (St. Louis University) Assistant Professor of Special Education, Behavioral Studies Department, School of Education, University of Missouri-St. Louis, 63121.

Lloyd I. Richardson, Ph.D. (George Peabody College for Teachers) Assistant Professor of Mathematics Education, Childhood Education Department, School of Education, University of Missouri-St. Louis, 63121.

Otto C. Bassler, Ph.D. (University of Maryland) Professor of Mathematics, George Peabody College for Teachers, Nashville, Tenn. 37203